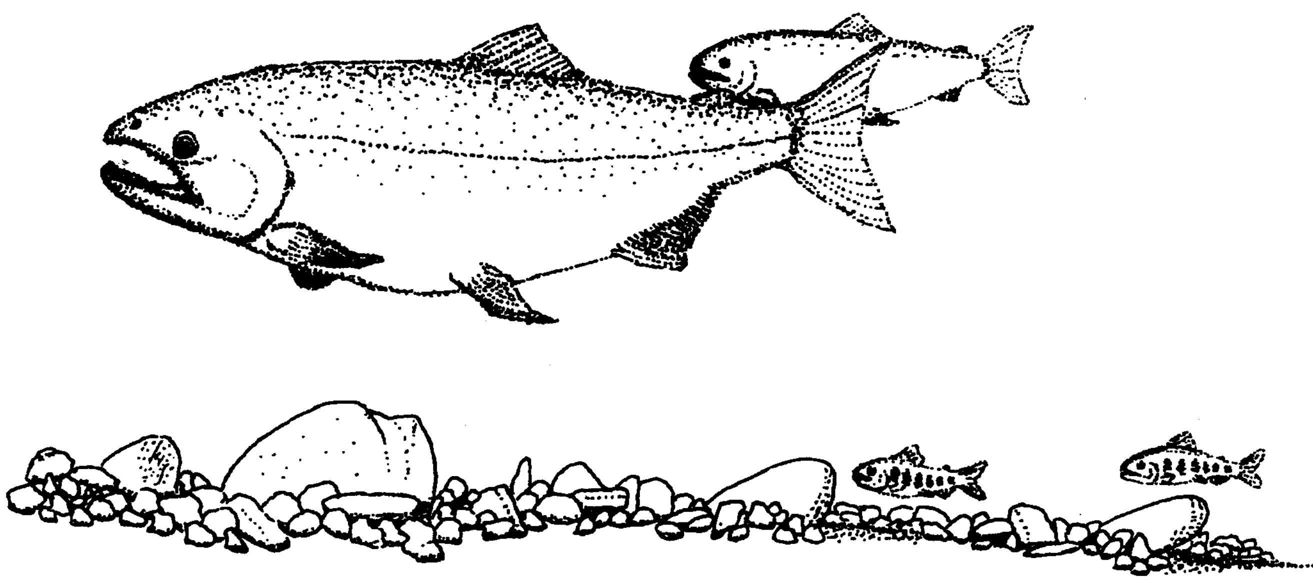
## U.S. Department of the Interior
## Fish and Wildlife Service

# PREDATION ON SOCKEYE SALMON FRY BY PISCIVOROUS FISHES IN THE LOWER CEDAR RIVER AND SOUTHERN LAKE WASHINGTON



WESTERN WASHINGTON FISHERY RESOURCE OFFICE

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# PREDATION ON SOCKEYE SALMON FRY BY PISCIVOROUS FISHES IN THE LOWER CEDAR RIVER AND SOUTHERN LAKE WASHINGTON

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# ABSTRACT

An inventory of piscivorous fishes was conducted in the lower 1.7 km of the Cedar River and southern Lake Washington to estimate predation on sockeye salmon fry (*Oncorhynchus nerka*) during their emigration and early lake rearing in the nearshore area. During their emigration to Lake Washington, sockeye salmon fry are vulnerable to predation by several species of piscivorous fish. Results indicated that the highest predation rates occur in the lower 600-m reach of the Cedar River. Except during high flows, this reach is mostly slow-velocity water backed up from Lake Washington. Cutthroat trout (*O. clarki*) stomachs contained the highest number of salmonid fry. Rainbow trout/steelhead (*O. mykiss*), steelhead smolts, coho salmon (*O. kisutch*), and prickly sculpin (*Cottus asper*) also appeared to be major predators of salmonid fry in the lower Cedar River. Smallmouth bass (*Micropterus dolomieui*), yellow perch (*Perca flavescens*), brown bullhead (*Ictalurus nebulosus*), and torrent sculpin (*C. rhotheus*) were present but not abundant and consumed few salmonid fry.

Results indicated that a large-scale dredging project which would deepen the channel and reduce water velocities in some areas would probably create additional foraging sites for piscivorous fishes and may increase overall predation on sockeye salmon fry emigrating to Lake Washington. However, the abundance of predators in the lower Cedar River does not appear to be very high until after the peak fry emigration period. Thus, the overall effect on fry survival would probably be small.

Low predation levels were observed in the littoral zone of southern lake Washington. Similarly to the lower Cedar River, cutthroat trout appeared to have the highest predation rates on sockeye salmon fry in Lake Washington. Small numbers of sockeye salmon fry were also observed in stomachs of juvenile coho salmon, rainbow trout, prickly sculpin, and smallmouth bass.

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# INTRODUCTION

Predation of emigrating juvenile salmonids by other fishes can be a significant source of mortality (Hunter 1959; Foerster 1968; Rieman et al. 1991). Although sockeye salmon (*Oncorhynchus nerka*) fry reduce their vulnerability to predators by migrating at night, predation rates can still be quite high. For example, Foerster (1968) estimated that losses to predatory fishes ranged from 63-84% over a four-year period. Sockeye salmon fry emigrating through the lower Cedar River are vulnerable to predation by several species of piscivorous fish.

Piscivorous fishes may also aggregate in response to emigration of juvenile salmonids (Meacham and Clark 1979; Collis et al. 1995). Little is known about the behavior of predatory fishes near the mouth of the Cedar River. Fish may aggregate (numerical response) near the mouth during the emigration period of sockeye salmon fry. A numerical response describes how the number of predators varies with prey density.

After sockeye salmon fry emigrate to Lake Washington, they often reside in the littoral zone for a short period (Martz et al. 1995). At this time, fry may also be vulnerable to several species of lake-dwelling fishes.

The Cedar River is subject to occasional flooding during peak winter flow events. Much of the flood damage occurs in the lower 1.7 km. Average annual flood damages in the lower river have been estimated at $670,000. Recently the U.S. Army Corps of Engineers and the City of Renton developed several alternatives for flood control. Alternatives included some level of dredging within the lower 1.7 km and relocation of certain levees.

One possible effect of any flood control measure in the Cedar River is a shift in fish distribution, abundance, and species composition. Because many of the fish species are potential piscivores, shifts in these fishes may have important effects on prey fish populations. Modifications such as dredging that change the river channel may reduce water velocities in some areas and cause sockeye salmon fry to be more vulnerable to predators.

The objectives of this study were to: 1) conduct an inventory of piscivorous fishes at the mouth of the Cedar River and the southern part of Lake Washington, 2) determine if there is a numerical response by predators to an increase in sockeye salmon fry abundance, 3) estimate consumption of sockeye salmon fry by piscivorous fishes, and 4) evaluate the potential effects of Cedar River flood control projects on predation of sockeye fry.

# STUDY SITE

The study site was the lower 1.7 km of the Cedar River and the southern end of Lake Washington (Figure 1). The Cedar River is the main tributary for the Lake Washington basin. The river originates at approximately 1,220 m elevation and over its 80-km course falls 1,180 m. The lower 35.1 km are accessible to anadromous salmonids. Landsburg Dam (Figure 1), a water diversion structure, prevents fish from migrating further upstream.

During normal flows, much of the lower 600 m of the Cedar River is slow velocity water that is backed up from Lake Washington (Figure 2). The amount of backed-up water varies depending on lake level and discharge. During winter (December to February) the lake level is kept low at an elevation of 6.1 m. Starting in late February the lake level is slowly raised to 6.6 m by May 1 and 6.7 m by June 1. The shoreline of the lower 600 m of river consists of steep banks, which are stabilized by wooden structures and gabions in many areas. The river section between 500 and 700 m is a transition zone with moderate water velocities. During winter, riffle and glide habitat is present; however, as the lake level rises this reach becomes mostly glide and pool habitat.

The upper reach of the Cedar River (700-1,700 m) is characterized by mostly shallow riffle habitat with moderate-to-high water velocities. The only slow water or pool-type habitats are some small backwaters along the shores and a side channel near the upper Boeing Bridge.

Lake Washington is a large monomictic lake in western Washington (Figure 1) with a total surface area of 9,495 hectares and a mean depth of 33 m. The lake typically stratifies from June through October. Surface water temperatures range from 4-6°C in winter to over 20°C in summer. Over 78% of the shoreline is comprised of residential land use.

We sampled predators along 4.4 km of shoreline in southern Lake Washington. The shoreline is highly developed with industrial and residential structures. Along the entire west shore and a small part of the east shore are residential homes with private docks and other structures (Figure 3). Renton Airport, Boeing plants, and a power plant are located on the south shoreline and several cement, steel, and wooden structures are present (Figure 3). Much of the east shore is contained within Gene Coulon Memorial Beach Park. Part of the park contains large wooden weirs and docks; however, much of this shoreline is relatively undeveloped.

For the most part, the littoral zone of southern Lake Washington that can be effectively sampled with an electroshocking boat is close to the shore and relatively narrow. Two notable exceptions are the Cedar River delta and a large shallow area near a small island in the southeast corner of the lake (Figure 3). The delta extended approximately 300 m from the river mouth, the first 100 m of which was gravel and sand and the remainder was mostly mud and silt. Little structure is available for cover. Depth generally ranged from 1.0-2.5 m. At the edge of the delta the bottom drops off rapidly to 20 m. The shallow area around the island consisted of sand and silt with some large woody debris. The remaining littoral zone of southern Lake Washington was composed of sand and gravel, with a few patches of cobbles and small boulders along the east shore.

# METHODS

Piscivorous fishes were sampled in the lower 1.7 km of Cedar River and southern end of Lake Washington during the emigration period of sockeye salmon fry (February - June). Both beach seining and electroshocking equipment were used to sample predators. Beach seining and electroshocking sites were sampled once every two to three weeks throughout the emigration period.

**Beach Seining**.-- Predatory fish were collected at three sites in lower Cedar River and eight sites in Lake Washington. We used a 30-m-long beach seine with a maximum depth of 2 m in the wings and 2.4 m in the middle (bag). The wings were made of 20-mm stretch mesh and the bag was made of 6-mm stretch mesh.

We only identified three suitable beach seining sites in lower Cedar River because of high water velocities and the presence of instream structures. All three sites were in the lower 700 m of the study reach (Figure 2). Generally, water velocities were slower at site 1, the lowest site, than at the other two sites. Each site was sampled one to five times in the afternoon and again after dark. The net was deployed from a small inflatable raft.

Eight beach seining sites were established in the southern end of Lake Washington (Table 1, Figure 3). The seine was deployed from a 7-m work boat. All sampling occurred at night. Initially each site was sampled once and, time permitting, a second time as well.

**Electroshocking**.-- Predatory fishes were also sampled with electroshocking equipment. The littoral zone of the lake and the lower reach of the Cedar River were sampled with a 6-m Smith-Root electroshocking boat. We used 60-Hz direct current to shock fish. Percent output was adjusted to deliver 4-5 amps of electricity to the water.

Five lower river transects of varying length were established (Table 1). We made one pass along the shoreline of each transect except at the lower Boeing Bridge sites, where the entire channel width was sampled. Most sampling occurred at night, beginning approximately one hour after dark. A few transects were also sampled during the day.

We established 15 transects in the littoral zone of Lake Washington. Transect boundaries were chosen based on changes in habitat and easily recognizable landmarks. We were able to sample virtually the entire shoreline of the study area. However, due to large catches in late May and June, we limited our sampling to nine transects (64% of total length) which were representative of the other transects. All were shoreline transects except two. One non-shoreline transect was located on the delta, which extended approximately 300 m from the lower Boeing Bridge. The other non-shoreline transect was the shallow area near the small island in the southeast corner of the lake (Figure 3). We made one pass along each transect, except at the large shallow areas where we made two to four passes. For transects along the south and east shores, we passed parallel to shore where the water depth was approximately 2-4 m. Along the west shore, which has numerous boat docks, we shocked the perimeter of each accessible boat dock, where water depths sampled ranged from 1-7 m. Effort was considerably greater per shoreline distance at the dock transects.

The upper reach of the Cedar River, which was too shallow for the boat electroshocker, was sampled with a Smith-Root backpack electroshocker. We were able to effectively sample side channels and shorelines with moderate water velocities, but we were ineffective at high water velocity sites in this reach. Seven backpack transects were established (Table 1). Four transects (numbers 6,7,9, and 10) were routinely sampled while others were sampled as time permitted. All backpack electroshocking was conducted at night.

Lengths of transects were measured with a hip chain. Distances from the mouth of the Cedar River were also determined.

**Catch rates**.-- To determine if there was a numerical response of predators to the mouth of the Cedar River during sockeye fry emigration, we calculated catch rates for beach seining and electroshocking. After capture, fish were anesthetized with MS-222 and identified to species. We separated *O. mykiss* into rainbow trout/steelhead, steelhead smolts, and hatchery rainbow trout based on body coloration, body shape, and the presence of eroded fins. There was some degree of qualitative assessment in making these distinctions. Resident rainbow trout and steelhead were often difficult to distinguish unless it was a steelhead smolt. During this study 314,500 hatchery rainbow trout were planted in Lake Washington.

Catch rates were estimated with catch per unit effort (CPUE). To compare between dates we calculated CPUE as the sum of transects sampled on each date. This included eight lake beach seining, nine lake electroshocking, and six river electroshocking transects. Catch rates were not calculated for river beach seining because changes in discharge and water level probably changed the catch efficiency between sample dates. Lake beach seining CPUE only included the initial set at each site. To compare locations within the study site, we grouped transects into four major areas (lake shore, south lake shore near Cedar River, delta, and lower river). Because little day sampling was done in the river, we only compared sites that were sampled at night. Catch per 100 m and catch per 10 minutes were calculated to normalize the data.

**Population size**.-- Population sizes of predatory fishes were estimated with an adjusted Petersen mark-recapture methodology (Ricker 1975). Approximate confidence intervals were obtained from a Poisson distribution table (Ricker 1975). Due to low catches in February-April, we only completed one mark-recapture estimate (May 1-3, 1995). We also attempted to estimate the population sizes on other dates by using differences in CPUE to adjust the original estimate. Fish were initially collected with electroshocking equipment. Fish were anesthetized with MS-222 and then marked with either a thread tag or an opercle punch. Lengths were measured to the nearest mm and weights were measured to the nearest g. Stomach samples were also taken from most fish. Fish were released along the same transect where they were caught. Fish were also collected the second time with electroshocking equipment.

Two important assumptions in a mark-recapture estimate are: 1) the second sample is taken from the same population as the first sample, and 2) marked and unmarked fish are equally vulnerable to capture. To meet these assumptions, we attempted to resample 3-6 h after the marked fish were released to minimize fish movements, and allow enough time between samples for fish to recover from the stress of electroshocking. However, to meet requirements of other aspects of this study, we only completed single-night mark-recapture estimates for the river and two lake transects. Eight other lake transects were resampled the following night after the fish were marked. Ideally, both mark and recapture sampling should occur on the same night to minimize fish movements. Visual observations have demonstrated that many dirurnally active freshwater species are generally inactive at night, in that they cease feeding and swimming (Emery 1973; Helfman 1981). Warner and Quinn (1995) also found that rainbow trout in Lake Washington were generally inactive and stayed close to shore at night.

In the published literature, the recommended sampling interval in mark-recapture studies involving electroshocking varies considerably. Mesa and Schreck (1989) found that a recovery period of 3-6 h after release seemed to be a reasonable assumption for cutthroat trout (*O. clarki*), but recommended that at least 24 h elapse between mark and recapture efforts. Schreck et al. (1976) suggested that rainbow trout require 6-12 h to return to normal preshock conditions. In contrast, mark-recapture field studies of juvenile coho salmon (*O. kisutch*) have shown that 1-2 h recovery time after release is sufficient to get an accurate population estimate (Peterson and Cederholm 1984; Rodgers et al. 1992). Peterson and Cederholm (1984) also found that waiting 24 h instead of 1 h did not improve the population estimate. Overall, we felt a period of 3-6 h would be reasonable for fish to recover in this study.

**Fish Movements**.-- Movements of predatory fish were determined with individually-numbered thread tags. After fish were captured during routine sampling, they were anesthetized with MS-222 and tagged just behind the dorsal fin. Due to time constraints, we only tagged fish that were likely to be piscivorous (> 145 mm FL). Fish were released at exactly the same location (beach seining) or at the middle of the transect (electroshocking) where they were captured. In subsequent sampling, the location and tag number of recaptures were recorded. Distance moved was estimated from the shoreline distance between the release and recapture sites. Fish recaptured in adjoining electroshocking transects were not considered to have moved substantially.

**Stomach samples**.-- After capture, stomach contents of most fish were removed using a gastric flushing apparatus modified from Foster (1977). Gastric lavage has been shown to be effective in removing stomach contents for many fish species. For example, Light et al. (1983) found the technique removed 98% of the stomach contents of brook trout (*Salvelinus fontinalis*) and 100% for slimy sculpin (*C. cognatus*). All stomach contents were put in plastic bags, placed on ice, and later froze. Samples remained frozen until laboratory analysis. Because gastric lavage is ineffective for some types of fish, such as ictalurids and cyprinids, we sacrificed these fish and the stomach (ictaluids) or entire digestive tract (cyprinids) was removed. Due to time constraints, most cottids were sacrificed, placed on ice, frozen, and their stomach contents were later removed in the laboratory.

In the laboratory, samples were thawed, examined with a dissecting scope, and divided into major prey taxa. We attempted to identify fish to species. Insects and crustaceans were identified to order, while other prey items were identified to major taxonomic groups. Each prey group was blotted by placing the sample on tissue paper for 15 s. Prey groups were weighed to the nearest 0.01 g. To reduce bias from different sized fish, prey weights were converted to percent body weight (Hyslop 1980).

Prey fishes that were slightly digested were easily identified to species. Fishes in more advanced stages of digestion were identified to family, genus, or species from diagnostic bones (Hansel et al. 1988), gill raker counts, pyloric caeca counts, or vertebral columns. The fork length of prey fishes was measured to the nearest mm. If a fork length could not be taken, the original fork lengths of prey fishes were estimated from measurements of standard length, nape to tail length (Vigg et al. 1991), or diagnostic bones (Hansel et al. 1988).

# RESULTS

## Catch

In February and March, few predatory fish were collected in the lower 1.7 km of the Cedar River (Figure 4, Table 2). We were unable to sample with electroshocking equipment in February due to high flows and lack of a suitable electroshocking boat. Beach seining catches were relatively low in February and March (Table 2) and electroshocking catches in March were also relatively low (Table 3).

Similarly to the lower Cedar River, catch rates of electroshocking and beach seining in the southern part of Lake Washington were generally low in February and March (Figures 5,6). Catch rates of most fish species were highest in May and June.

Catch rates were also compared between different areas. Rates using distance shocked or time shocked gave similar results (Figures 7,8). The lowest catch rates were observed in the river delta. Catch rates of most salmonids were highest in the lower river, while catch rates of non-salmonid species were highest in the lake.

**Salmonidae**.-- In the lower Cedar River, the numbers of cutthroat trout caught increased markedly in June (Figure 4). Most cutthroat trout (64%) were between 140-200 mm FL (Figure 9). Twenty-one fish (7%) were > 300 mm FL. Few cutthroat trout < 120 mm Fl were seen.

Rainbow trout appeared to be well distributed throughout the lower Cedar River and southern lake Washington. In the lower Cedar River, they appeared to inhabit areas of higher water velocities than cutthroat trout. Catch rates of rainbow trout generally peaked in April and early May (Figures 4,5,6). In June, when water temperatures were warmer, few rainbow trout were collected along the shoreline of Lake Washington.

During mid-May through June, hatchery rainbow trout were present in the lower Cedar River. A small group (1,250 fish) of large hatchery rainbow trout (mean, 114 g) was released at Gene Coulon Park on April 7, 1995. However, based on fish size, this group of fish was not detected in Cedar River. Some of these fish were collected in April along the east shore near the stocking site. Most hatchery rainbow trout collected in the lake and river were probably from later releases along the west shore at either Rainer Beach Park, Stan Sayres Park, or Magnuson Park (4.3, 9.5, 20.0 km, respectively, from the mouth of the Cedar River). A total of 312,700 fish (mean, 23.1 g) was released over a 15-day period in May 1995. The first releases were at Rainer Beach Park and Stan Sayres Park on May 8, 1995. Three days later we began to collect these fish in the Cedar River, mostly in the lower 700 m, although one fish was caught just downstream of Logan Street Bridge (Rkm 1.7). The highest catch of hatchery fish was along the east shore in Gene Coulon Park.

Small numbers of coho salmon smolts were collected in March and April. Most coho salmon that were collected in the Cedar River in April (5 of 7) were captured in the upper reach. In early May, coho salmon were particularly abundant in the lower 500 m (Figure 4). In Lake Washington, coho salmon abundance also peaked in early May (Figures 5,6). Coho salmon < 200 mm FL in Lake Washington (mean, 133.8 mm FL; range, 100-175 mm FL) tended to be larger than those collected in the lower Cedar River (mean, 112.1 mm FL; range, 91-142 mm FL).

**Cyprinidae**.-- Overall catch rates of northern squawfish (*Ptychocheilus oregonensis*) were low (Figure 5). Most northern squawfish were collected in May. No northern squawfish were collected in the Cedar River or its delta.

Small northern squawfish were collected primarily along the south lake shore. Forklengths of northern squawfish ranged from 115-558 mm FL (Figure 10).

One large tench (528 mm FL; *Tinca tinca*) was collected along the west shore.

**Ictaluridae**.-- Small numbers (*N* = 23) of brown bullhead (*Ictalurus nebulosus*) were collected in southern Lake Washington. The highest CPUE occurred in June (Figure 5). Size of brown bullhead ranged from 180 to 315 mm FL (mean, 255 mm FL; Figure 10). The only brown bullhead collected in the Cedar River was captured in the upper reach.

**Centrarchidae**.-- A total of 99 smallmouth bass (*Micropterus dolomieui*) were collected in the southern end of Lake Washington. Catch rates were highest in mid-May and June (Figures 5,6). The highest catch rates were observed along the east shore from Gene Coulon Park to Coleman Point. Only one smallmouth bass was collected along the west shore. Four smallmouth bass were collected in the Cedar River, near the lower Boeing Bridge. An additional 12 smallmouth bass were collected near the Renton Airport.

Small numbers of largemouth bass (*N* = 15; *M. salmoides*) and pumpkinseed (*N* = 19; *Lepomis gibbosus*) were also collected. All largemouth bass were collected along the east shore in Gene Coulon Park. Eleven out of the 15 largemouth bass collected were < 200 mm FL. The remainder were large adults (range, 335-442 mm FL). Most pumpkinseed were captured near a marina/small boulder area in Gene Coulon Park. Other pumpkinseed were collected along the south shore or at other sites on the east shore.

**Percidae**.-- Most yellow perch (*Perca flavescens*) were collected in the lake. Similarly to smallmouth bass, a few yellow perch (*N* = 3) were also collected in the river, near the lower Boeing Bridge. Catch rates of yellow perch were substantially higher in mid-May and June than in earlier samples.

**Cottidae**.-- Based on snorkeling observations, beach seining, and electroshocking, prickly sculpin (*C. asper*) appeared to be abundant throughout the study area. However, because cottids were difficult to sample with electroshocking equipment and can avoid beach seines (Parsley et al. 1989) we were unable to compare the relative abundance of prickly sculpin among areas and dates. Size of prickly sculpin collected for stomach analysis ranged from 65-236 mm FL.

## Population size

The results of our mark-recapture population estimates are presented in Table 3. For most species, we were unable to mark and recapture many fish. Thus, an individual recaptured fish can have a large impact on the population estimate. According to Ricker (1975) there is little chance of statistical bias if MC/N (see Table 3) is greater than four. For all of our estimates, MC/N was < 1.5, thus indicating a high potential for some type of bias.

Although our estimates are probably biased somewhat due to the small sample sizes, the results suggest that population sizes of predatory fishes in the lower Cedar River are generally small. Population estimates along the shoreline of southern Lake Washington provide a general idea of the abundance of predatory fishes in the littoral zone. Results also indicate that there was no aggregation of predators along the shore near the mouth of the Cedar River. Predator population sizes for other dates were also estimated by using differences in CPUE to adjust the May 1-3 estimate (Figure 11, Appendix A). Generally, population sizes were low in February-April but increased dramatically in May and June (Figure 11, Appendix A).

## Fish Movements

A total of 443 fish were marked with individually-numbered thread tags. Fifty-three fish were recaptured at least once during the sampling period (Table 4, Appendix B). Ten fish were recaptured a second time and three were recaptured a third time.

**Salmonidae**.-- Of the species tagged, only cutthroat trout appeared to move appreciably from their release site. Ten out of 27 cutthroat trout were recaptured at a distinctly different area than their release site (Figure 12). The remainder were recaptured at either the same site or at an adjacent transect. Fourteen rainbow trout were also recaptured, all but two of which were recaptured at the site where they were released (Table 4). One rainbow trout was recaptured at a west Mercer Island beach seining site (8 km from release site) as part of another study. Of the two coho salmon recaptured, one was recaptured in the same location and the other, a larger fish (242 mm FL), had moved slightly.

There was some movement of cutthroat trout to the mouth of the Cedar River but we were unable to detect any large-scale movement of fish to that location. Four cutthroat trout moved from the lake to the vicinity of the river mouth. Alternatively, two cutthroat trout and a rainbow trout moved from the lower reach Cedar River to shoreline areas in the lake. Most of these movements occurred in May or June (Appendix B) and thus, did not appear to be closely related to sockeye fry abundance.

Predatory fishes in the upper reach appeared to move little. Although only five fish were marked in the upper reach of the Cedar River, four were later recaptured (three rainbow trout and one cutthroat trout) in the same location as they were released.

**Other fish**.-- Of the seven smallmouth bass recaptured, five were in the same area where they were released, one was recaptured in an adjacent transect, and the other was collected a short distance away. One largemouth bass was also recaptured in the same location that it was released.

Two of seven marked prickly sculpin were recaptured. Both were recaptured at the same beach seining site where they were released. One prickly sculpin was recaptured three times. Movement of prickly sculpin appeared to be minimal.

Small numbers of steelhead, chinook salmon (*O. tschawytscha*), hatchery rainbow trout, and yellow perch were also marked (Table 4). None of these fish were recaptured.

## Stomach analysis

We were able to identify most salmonid fry as sockeye salmon (77.6%). Three were identified as mountain whitefish (0.3%). The remaining 22.1% were unidentified fry. This information, as well as catch data from a fry trap at Rkm 0.7 (D. Seiler, WDFW, personal communication), suggests the remaining unidentified salmonid fry were probably also sockeye salmon fry.

Stomach analysis and catch data from electroshocking indicated that, within the Cedar River study area, the majority of predation on sockeye salmon fry occurs in the lower 600-m reach (Table 5). However, predation rates on salmonid fry were still relatively high in the upper reach. Additionally, fish in the upper reach were less abundant and their average size was smaller than in the lower reach (Table 5). Low numbers of predatory fish in the upper reach appeared to be primarily due to the lack of suitable habitat.

Based on beach seining results, consumption of salmonid fry and numbers of predatory fish appear to increase at downstream sites (Table 6). At site 3, the most upstream site, no consumption of salmonid fry was detected (Table 6).

Predation levels on sockeye salmon fry were considerably lower in the lake than in river (Tables 2,7,8,9).

**Salmonidae**.-- Of the fish species examined, cutthroat trout had the highest number of salmonid fry per stomach in both the lower Cedar River and southern Lake Washington (4.2 and 0.2 fry/stomach, respectively). Consumption of sockeye salmon fry was highest in cutthroat trout < 250 mm FL. In the lower Cedar River, sockeye salmon fry were the most important diet item (Table 10). Other major prey items included aquatic insects, larval catostomids (14-15 mm TL), and fish eggs. Although the diet of large cutthroat trout (> 250 mm FL) included some salmonid fry, larger prey fish such as adult longfin smelt (*Spirinchus thaleichthys*; 90-97 mm FL) and sockeye salmon smolts (100 mm FL) were more important.

In southern Lake Washington, only 5% of the cutthroat trout stomachs examined contained any salmonid fry. Most salmonid fry (21 of 36 salmonid fry) observed were from one fish (197 mm FL). Other prey fish (other salmonids, longfin smelt, cottids, and larval catostomids) composed 23% of the diet (Table 11). Insects, primarily adult and pupal chironomids, made up 23% of the overall diet.

Similarly, stomachs of rainbow trout from the lower Cedar River contained large numbers of salmonid fry (3.9 fry/stomach). One fish had consumed 79 salmonid fry. Besides salmonid fry, aquatic insects and larval fish were important in their diet. Large rainbow trout (> 300 mm FL) often had few prey items in their stomach. These fish may have moved into the river to spawn.

Only one salmonid fry was observed from 62 rainbow trout examined from southern Lake Washington. Longfin smelt and yellow perch made up the majority of the diet for rainbow trout > 200 mm FL (Figure 14). Pupal and adult chironomids were also frequently consumed. Invertebrates, primarily pupal and adult chironomids and oligochaetes, comprised the majority of the diet for rainbow trout 100-199 mm FL (Table 11).

The diet of hatchery rainbow trout in the lower Cedar River and Lake Washington was dominated by aquatic insects (Table 10,11). Exuviae and terrestrial insects were also common in their stomachs. In Lake Washington, zooplankton made up only 3.2% of the diet. Larval catostomids (14-15 mm TL) and larval cottids were important in their diet in June. One sockeye salmon fry was consumed by a hatchery rainbow trout from the lower Cedar River.

Due to the low population size of steelhead, we attempted to minimize handling of steelhead smolts. Only a few stomach samples were collected (8 of 24 smolts). Of these, four samples were collected shortly after a large hatchery release of sockeye fry on March 30, 1995, and one fish contained 27 salmonid fry while another contained 10 salmonid fry.

Juvenile coho salmon also appeared to be a major predator of sockeye salmon fry in both the lower and upper reach of the lower Cedar River. Five coho salmon collected in the upper reach in April contained 23 salmonid fry. Forty coho salmon collected in the lower reach May 3 contained an average of 2.05 salmonid fry/stomach. On May 11 and May 15, coho salmon were present but in reduced numbers and consumption of salmonid fry was greatly reduced (0.23 and 0.07 salmonid fry/stomach, respectively). Of the few coho salmon ($N$ = 6) that were collected in June, no salmonid fry were present in their stomachs.

Other major prey items of juvenile coho salmon in the lower Cedar River included adult chironomids, ephemeropterans, and plecopterans. Exuviae were also common in their stomachs.

In southern Lake Washington, a total of ten salmonid fry were observed from 100 coho salmon stomachs. Only cutthroat trout had a higher number of salmonid fry per stomach. Predation on salmonid fry was only detected in late April and early May. Other prey fish included longfin smelt, pumpkinseed, and larval fish. Seventy-five percent of the diet of coho salmon was composed of aquatic insects, primarily pupal chironomids.

Stomachs of mountain whitefish (*Prosopium williamsoni*) were only examined from May river sampling. No salmonid fry was present in 17 stomachs examined. The diet of mountain whitefish included mostly benthic prey such as fish eggs, larval caddisflys, and other aquatic insects (Table 12). A few larval catostomids were observed in two stomachs.

Other salmonids collected for stomach analysis included one adult Atlantic salmon (*Salmo salar*), seven juvenile chinook salmon, and six juvenile sockeye salmon. The stomach of the Atlantic salmon was empty. Most chinook salmon stomachs contained aquatic insects. One unidentified fish was observed in a chinook salmon (280 mm FL) stomach. Three of the six sockeye salmon stomachs examined were empty. One larger sockeye salmon (245 mm FL) had consumed an unidentified fish and another sockeye salmon (139 mm FL) had consumed a juvenile longfin smelt (52 mm FL). Chironomids and *Neomysis* were also present.

**Cyprinidae**.-- Most large northern squawfish examined (> 300 mm FL) had empty digestive tracts (64%). Prey items found in the other fish included an unidentified salmonid, a three-spine stickleback (*Gasterosteus aculeatus*), crayfish, and plant material (Table 13). Forty-six percent of the diet of small northern squawfish (< 250 mm) consisted of larval fishes (catostomids and cottids, Figure 15). Isopods (26%), terrestrial insects (11%), and plant material (12%) were also present.

The digestive tract of the single tench collected contained a large amount of fish eggs, snails, and small clams.

**Ictaluridae**.-- The single brown bullhead collected in the Cedar River had consumed one coho salmon presmolt (103 mm FL). No other prey items were present. The diet of brown bullhead collected in the lake was dominated by fish eggs (94% by weight). The remainder of the diet included various benthic invertebrates. No fish were seen in their diet.

**Centrarchidae**.-- The diet of smallmouth bass in southern Lake Washington was predominantly non-salmonid fish (Table 13, Figure 17). Cottids composed 38% of the diet. Peamouth (11%), yellow perch (9%), and longfin smelt (4%) were also important in their diet. Juvenile coho salmon and unidentified salmonids (non fry size) composed the majority of salmonids consumed (Table 13). Two sockeye salmon fry were also consumed but made up less than 0.1% of the diet. Consumption of salmonids was observed primarily in fish that were collected near the mouth of the Cedar River. The non-fish component of the diet consisted primarily of crayfish (Table 13).

The diet of the few smallmouth bass (*N* = 4) collected in the lower Cedar River also consisted primarily of cottids (91% by weight). One three-spine stickleback (5%) and three salmonid fry (1%) were also present in the stomach samples.

Cottids (51%) and *Neomysis* (43%) were the dominant prey items of largemouth bass < 200 mm FL (Figure 17). Three largemouth bass > 200 mm FL collected before May all had empty stomachs. The single largemouth bass > 200

FL collected in June contained one juvenile chinook salmon, two cottids, and one three-spined stickleback.

Three stomachs of pumpkinseed were also examined but all were empty.

**Percidae**.-- Before mid-May, few yellow perch were collected and of those 67% had empty stomachs. Several ripe males were observed in the first two weeks of May, indicating they were near their spawning season. However, of the yellow perch examined in June, only 4% had empty stomachs. Their diet included larval and juvenile cottids (11-28 mm TL) and larval catostomids (14-15 mm TL). Fish eggs and leeches were also present. No salmonid fish were observed in their stomachs.

**Cottidae**.-- A total of 123 prickly sculpin from the lower Cedar River were sampled for stomach contents, of which 28% contained salmonid fry. Much of the predation noted in prickly scuplin occurred shortly after a hatchery release of sockeye salmon fry on March 30. Consumption of other sockeye fry occurred primarily in April. Few sockeye salmon fry were consumed in May and June (Figure 18). Prickly sculpin > 140 mm FL tended to consume larger prey than sockeye salmon fry. Brook lamprey (*Lampetra richardsoni*), longfin smelt, and crayfish were the most important prey items. For prickly sculpin 100-139 mm FL, leeches were the most important prey item in May and June. Prickly sculpin diet also consisted of other benthic prey such as fish eggs and small cottids.

Fish eggs were an important prey item for all size categories of prickly sculpin in southern Lake Washington (Figure 18). Various benthic invertebrates were also eaten, which included oligochaetes, amphipods, and crayfish. Aquatic insects made up a relatively small part (1%) of the diet. Overall, fish made up 11.4 % of the diet by weight. Most prey fish consumed were small cottids. Only one sockeye salmon fry was found in 91 stomachs examined.

Two torrent sculpin (*C. rhotheus*) were also collected. Both were collected in the upper reach close to shore. Aquatic insects were the only prey items present in their stomachs.

# DISCUSSION

Based on CPUE and population estimates there did not appear to be any obvious numerical response of predators at the mouth of the Cedar River due to fry emigration. CPUE indicated that the peak abundance of predatory fishes occurs after the peak abundance of sockeye salmon fry. We attempted to estimate the population sizes during the first week of May. Due to the small number of recaptures, the accuracy of our estimates is questionable. However, the data suggest that during much of the emigration period, there are few predators at the mouth of the Cedar River. Thread-tag recapture information suggested there was some movement of cutthroat trout to the mouth of the river, but we were unable to detect any large-scale movement of fish in response to sockeye salmon fry emigration. Besides availability of sockeye salmon fry, movement of predatory fishes into the lower Cedar River may result from increased abundance of larval catostomids, aquatic insects, and other prey. Additionally, in late May and June the river water temperatures (10-12°C) can be cooler than the lake surface waters (13-16°C), which may cause some coldwater fish such as cutthroat trout and rainbow trout to move into the river.

Because the abundance of predatory fishes varied temporally, consumption of sockeye salmon fry probably also varied greatly. During the early part of the sockeye salmon fry emigration, few predatory fish were present. In addition, high flows and increased turbidity would probably reduce foraging ability of piscivorous fishes (Ginetz and Larkin 1976). The reactive distance of visual predators is greatly reduced with increased turbidity (Vinyard and O'Brien 1976; Crowl 1989). As flows decreased and temperatures increased (April-June), the number of piscivorous fishes appeared to increase. Because sockeye salmon fry emigration peaks in mid-April, piscivorous fishes would have the greatest impact on the late-emerging part of the sockeye salmon fry population.

Light levels in the lower Cedar River may also affect predation rates on sockeye salmon fry. In an experimental stream, predation of sockeye salmon fry by rainbow trout was higher during moonlight nights than cloudy nights (Ginetz and Larkin 1976). Patten (1971a) also found that predation levels of torrent sculpin increased during moonlight nights. In the lower Cedar River there are several light sources from the Renton Airport and the Boeing plant that may artificially increase predation rates.

Results indicate that the highest densities of piscivorous fishes and highest predation rates on sockeye salmon fry occur in the lower 600-m reach of the Cedar River. This reach probably provides the best habitat for piscivorous fishes because it is relatively deep and various instream structures are present. The left and right banks have wooden structures which provide cover and the lower bridge has overhead cover, woody debris, and steel beams which also provide refuge. Lonzarich and Quinn (1995) found that water depth appeared to be more important than structure in determining the distribution of coastrange sculpin (*C. aleuticus*) and large age 1+ cutthroat and steelhead trout, while structure alone (age-0 trout) or both structure and depth (coho salmon) were important for small salmonids. The depth distribution of fishes in lotic ecosystems has been shown to be influenced by predation risk (Power 1987; Schlosser 1988; Harvey and Stewart 1991). For large fish, the highest risk occurs in shallow habitats from wading and diving predators whereas for small fish the highest risk occurs in deep habitats from piscivorous fishes. Overall, it appears that a dredging project to deepen the channel of the Cedar River would probably create additional foraging sites and increase the overall abundance of piscivorous fishes.

Although the predator population would likely be increased if the river channel is deepened, it is difficult to predict how many fish would be added.

Fish abundance can be influenced by changes in abiotic factors such as water depth, structural complexity, and water velocities as well as changes in various biotic factors such as food availability, predation risk, and inter- and intra-specific competition. In the lower 600-m reach, the shoreline habitat appeared to be the preferred habitat of piscivorous fishes because it is relatively deep and contains instream structure for cover. Therefore, the number of fish per meter of shoreline we observed in the lower reach (excluding the lower Boeing Bridge) may be a reasonable predictor of the increase in abundance if the river channel is deepened. This would only be appropriate for the additional stream length of backed-up water from Lake Washington. In addition, this estimate may not be valid if the cross-sectional shape of the riverbed is changed from the present condition.

At night, the river delta contained few predaceous fish, but we observed several western grebes foraging. The delta had little cover and the presence of western grebes may inhibit piscivorous fishes from foraging in this potentially risky environment. Piscivorous fishes may, however, reside on the edge of the delta where water depths are substantially greater. But, due to the deep water, electroshocking equipment is probably ineffective in sampling them. Other Lake Washington studies, which involve gill net sampling, have suggested that piscivorous fish are often near the mouth of the Cedar River (Olney 1975; Beauchamp 1987). Other differences may also be due to changes in habitat conditions. Previously, the delta may have been more complex with more woody debris and several channels around small islands. Some fish, such as cutthroat trout, may only use the delta to move between foraging locations and thus are vulnerable to gill nets, but are rarely encountered during electroshocking.

**Salmonidae**.-- In both Cedar River and southern Lake Washington, cutthroat trout appeared to have the highest consumption rates of sockeye salmon fry. Cutthroat trout were also the only species observed to consume sockeye salmon presmolts. There were, however, several unidentified salmonids observed in cutthroat trout and other species. Other studies have also indicated that cutthroat trout often have higher predation rates of juvenile sockeye salmon than other predators (Foerster 1968). Beauchamp et al. (1995) estimated that per-capita predation by cutthroat trout was 25 times greater than predation by northern squawfish in Lake Ozette, Washington. In summarizing the relative importance of different predators in Cultus Lake, Foerster (1968) considered one cutthroat trout equivalent to five northern squawfish and 20 coho salmon.

Comparisons with earlier work on the Cedar River indicate that the abundance and distribution of cutthroat trout may have changed. From 1983 to 1985, Beauchamp (1995) conducted 10 electroshocking surveys (February-May) in the lower 9 km of the Cedar River during the sockeye salmon fry emigration. A total of 12 cutthroat trout were collected. Most had empty stomachs and none had eaten sockeye salmon fry (Beauchamp 1987). In contrast, we sampled 113 cutthroat trout within the lower 1.7 km and these trout averaged 4.2 fry/stomach. In part, this may be due to differences in electroshocking equipment and time of sampling (Beauchamp surveyed during the day). Additionally, Beauchamp did not survey the lower 250 m. Evidence from gill net samples suggests that the cutthroat trout population has increased in Lake Washington (D. Beauchamp, personal communication). Differences may also be due to habitat changes in the lower 600-m reach. In 1983-1985, this reach was riverine with moderate to high water velocities and water depths of ≈0.3-0.5 m. A large delta was present downstream of the lower Boeing Bridge, and the river extended beyond the bridge. In 1995, however, water depths in this reach were ≈0.8-1.5 m deep and contained mostly slow-velocity water backed up from Lake Washington.

Most predation on sockeye salmon fry was observed in cutthroat trout less than 250 mm FL. Larger cutthroat trout consumed larger prey fish such as longfin smelt and sockeye salmon presmolts. In earlier work with Lake

Washington cutthroat trout, winter and spring predation on sockeye salmon fry was only observed in fish > 250 mm FL (Beauchamp et al. 1992). However, sockeye salmon fry made up less than 2% of their diet. A major difference between our two studies is the relative sample sizes of small (< 250 mm FL) and large cutthroat trout (> 250 mm FL). Only 8 of 91 (9%) cutthroat trout that Beauchamp et al. (1992) sampled in the spring of 1985 were < 250 mm FL. In contrast, 158 of 172 (92%) cutthroat trout we collected in southern Lake Washington were < 250 mm FL. The relative differences are probably due to the type of sampling gear used. Large cutthroat trout may be in deeper water than we were able to sample effectively with electroshocking equipment. Gill nets used by Beauchamp et al. (1992) may have selected for larger fish due to the mesh sizes used. Differences could also reflect a change in the population structure of cutthroat trout. In addition, Beauchamp et al. (1992) sampled throughout the lake, while we only sampled its southern end.

Rainbow trout also appeared to be an important predator of sockeye salmon fry in the Cedar River. However, little predation was noted in southern Lake Washington. Rainbow trout often can prey heavily on emigrating salmonid fry in streams, but predation rates on sockeye salmon in lakes can be relatively low. Rainbow trout were found to be the principal predator on emigrating sockeye salmon fry in a tributary to Babine Lake (Foerster 1968). Fresh and Schroder (1987) also found rainbow trout were an important predator of emigrating chum salmon fry. In southern Lake Washington the diet of rainbow trout < 250 mm FL consisted mostly of insects. In lakes the diet of rainbow trout < 250 mm FL often consists of insects and zooplankton, while fish make up a small percent of the diet (Beacham and McDonald 1982; Beauchamp 1990). Rainbow trout > 250 mm become progressively more piscivorous as they get larger. Beauchamp (1990) reported that only rainbow trout > 250 mm ate juvenile sockeye salmon in Lake Washington. We sampled few rainbow trout > 250 mm FL in Lake Washington and thus were not able to evaluate their consumption of sockeye salmon.

In addition, rainbow trout are generally less piscivorous than cutthroat trout. Nilsson and Northcote (1981) found that in a sympatric population, rainbow trout exploited limentic surface and midwater prey whereas cutthroat trout utilized more littoral prey and were much more piscivorous. Studies of other lentic systems have also indicated that cutthroat trout are often more piscivorous than rainbow trout (Idyll 1942; Wurtsbaugh and Modde 1988).

Although juvenile coho salmon consumption rates of emigrating sockeye salmon fry are usually less than resident salmonids, they can be the most important predator because they are often substantially more numerous than other salmonids (Semko 1960 cited in Foerster 1968; Foerster 1968). Ruggerone and Rogers (1992) estimated that juvenile coho salmon consumed 59% of emerging sockeye salmon fry in Chignik Lake. In the lower 600-m reach of Cedar River, coho salmon appeared to be present in large numbers only during May. However, we observed some predation on sockeye salmon by juvenile coho salmon in the upper reach in April. Little is known about their consumption of sockeye salmon fry in other parts of the Cedar River, although the general lack of pools and woody debris in the Cedar River suggests the overall coho salmon population may be relatively small.

In southern lake Washington, juvenile coho salmon were also observed to consume sockeye salmon fry. However, they appeared to be abundant only in May and June. Shoreline electroshocking and beach seining probably gave an adequate estimate of the overall predation level on sockeye salmon fry by juvenile coho salmon. In lakes, juvenile coho salmon are predominantly found in the littoral area and are often just a few meters from shore (Mason 1974; Ruggerone and Rogers 1992).

Hatchery rainbow trout were released after most of the sockeye fry had emigrated and did not appear to be a major predator. However, because they quickly moved into the Cedar River, they could be a significant predator of sockeye salmon fry if they are released earlier during the peak of the fry emigration. Hatchery rainbow trout may also require days or weeks before they learn how to forage effectively in low light conditions on mobile prey such as salmonid fry. Beauchamp (1987) found that hatchery steelhead stomachs did not contain any sockeye salmon fry while 22% of the wild steelhead caught concurrently had consumed fry.

Because we only collected stomach samples of mountain whitefish in May, we cannot fully evaluate their consumption of sockeye salmon fry. Few diet data have been collected on mountain whitefish during salmonid fry emigration or early lake rearing. Ricker (1941) reported that one mountain whitefish from Cultus Lake consumed 10 small sockeye salmon but no predation was noted in 52 other mountain whitefish. Mountain whitefish have been shown to consume other prey fishes in some riverine (Brown et al. 1992) and lacustrine systems (McHugh 1940). Because spawning usually occurs in the fall from October to December (Wydoski and Whitney 1979), they probably inhabit the lower Cedar River and forage on available benthic insects, fish eggs, and larval fish. Mountain whitefish appeared to be abundant in the lower reach of the Cedar River, they were relatively large fish, and thus, potentially could consume large numbers of sockeye salmon fry. Predation on fry may be particularly noticeable after large hatchery releases.

**Other fish**.-- In laboratory experiments and other artificial situations, cottids have been shown to readily feed on juvenile salmonids (Clary 1972; Patten 1971a). However, under most natural conditions, predation on salmonids by cottids is rare (Moyle 1977). Cottids appear to feed on salmonids in some situations such as during large emigrations of salmonid fry (Hunter 1959; Foerster 1968) or during early stream rearing of salmonids (Patten 1962; Hillman 1989). Hunter (1959) estimated that cottids consumed from 10-28% of emigrating pink salmon fry. In the Cedar River, prickly sculpin appeared to be an important predator of sockeye salmon fry. The apparent large population of prickly sculpin and observed predation on sockeye salmon fry indicate that further work is needed to assess their overall impact on sockeye salmon fry survival.

The lower 500 m of the Cedar River appears to have a large population of prickly sculpin > 140 mm FL. However, they rarely consumed sockeye salmon fry. Instead they appeared to select large benthic prey such as brook lamprey, cottids, and adult longfin smelt. Few studies have sampled enough large prickly sculpin to draw any conclusions about their overall diet. Rickard (1980) found that in Lake Washington 29% of the diet of prickly sculpin > 120 mm consisted of fish. The prey species ingested was not given. *Neomysis* and crayfish were also important in their diet.

Much of the predation we noted in prickly scuplin occurred shortly after a hatchery release of 383,000 sockeye salmon fry. Foerster (1968) reported that after a hatchery release of sockeye salmon fry, one cottid was collected that contained 111 fry. Following the release of hatchery chinook salmon fry (mean, 59 mm FL), prickly sculpin contained an average of 0.6 fry per stomach (Patten 1971b). We collected cottids in beach seine sets at the same time that sockeye salmon fry were collected. Thus the stomach samples could have been biased due to sculpin feeding while in the net. However, beach seines were deployed and retrieved quickly. Net feeding should have been minimal. Prickly sculpin appear to be an important predator of sockeye salmon fry when fry are present in large numbers such as after a hatchery release.

Although northern squawfish is an abundant predator in Lake Washington (Bartoo 1977), we were only able to collect a few specimens. Low catch rates were probably caused by sampling only the littoral zone. In winter, northern squawfish are concentrated near the bottom in deep water (Olney 1975). They move to shallower water and are closer to the surface in the spring and summer. We observed increased catches of northern squawfish in May. Offshore gill nets are probably a more effective method of sampling northern squawfish in winter and spring. Peak consumption of sockeye salmon by northern squawfish occurs in winter and fall when northern squawfish move to the limnetic zone (Ricker 1941; Olney 1975).

Northern squawfish (> 300 mm) are often important predators of juvenile salmonids including sockeye salmon; however, there is little evidence that they consume sockeye salmon fry to any large extent. Presumably, northern squawfish occupy deep water during late winter and early spring and there is little overlap in habitat during the emigration and early lake rearing period of sockeye salmon fry. We did not observe any northern squawfish in the lower Cedar River or near the mouth of the river. Olney (1975) stated that northern squawfish were found in winter at the mouth of the Cedar River but were feeding on longfin smelt. Larger northern squawfish (> 300 mm FL) may also select larger prey such as longfin smelt, cottids, juvenile salmonids, and crayfish. For example, in the Columbia River, northern squawfish 250-349 mm FL often consumed subyearling chinook salmon (35-85 mm FL) whereas fish > 350 mm FL consumed primarily yearling salmonids (Tabor et al. 1993). Larval fish were the most important prey item of 11 small northern squawfish (< 250 mm FL) examined. However, no predation on juvenile sockeye salmon fry was observed. Olney (1975) also did not observe predation on sockeye salmon by northern squawfish < 300 mm FL. Sample sizes of northern squawfish need to be greatly increased to determine the overall importance of sockeye salmon fry in their diet.

Brown bullhead did not appear to be a major piscivore in southern Lake Washington. No fish remains were found in the stomachs of brown bullhead. Instead, their diet was dominated by fish eggs. Imamura (1975) also found that fish eggs made up approximately 30% of the diet of adult brown bullhead (> 200 mm FL) in Union Bay in June. He examined 847 stomachs of brown bullhead from Union Bay and no salmonid fry or smolts were found. August was the only month when prey fish were important in their diet; cottids and yellow perch made up 18% of the diet (Imamura 1975). Overall, prey fish do not appear to make up a substantial portion of brown bullhead diet in Lake Washington. In contrast, the only brown bullhead we collected in the Cedar River had consumed a coho salmon smolt. However, it is doubtful that brown bullhead are common in the Cedar River. Typically, brown bullhead prefer lentic systems with aquatic vegetation or slow-moving rivers (Imamura 1975).

Although a few sockeye fry were consumed by smallmouth bass, their overall impact on fry emigration and early rearing was probably minimal. Smallmouth bass did not appear to be actively feeding until May when water temperatures were ≥ 10°C. Because smallmouth bass select areas of reduced water velocities (Rankin 1986), they are probably rare in the Cedar River and restricted to the mouth and a few deep pools. The only area where smallmouth bass were observed to have consumed sockeye salmon fry was near the mouth of the Cedar River, where 15 smallmouth bass were collected near the lower Boeing Bridge, either in the river or near the Renton Airport ramp. Smallmouth bass may move into this area due to the availability of other fishes. Although they consumed five salmonid fry, most of the ingested prey consisted of other fish which included two coho salmon smolts, 24 cottids, and three other fish. Because these fish were mostly > 300 mm FL, they probably selected for larger prey than sockeye salmon fry. Some authors have suggested that smallmouth bass may actually benefit salmonid species by preying on other piscivorous species (Bennett et al. 1991; Fletcher 1991). In some situations, adult smallmouth bass consume small prey items. Adult smallmouth bass been observed to prey on larval fish in a few areas of the Snake River (R. Tabor, unpublished data). In Brownlee Reservoir, smallmouth bass > 200 mm FL were forced to subsist on zooplankton because of the low availability of more preferred prey like fish and crayfish (Dunsmoor et al. 1991).

Based on catch rates and diet, largemouth bass did not appear to be a major factor in sockeye salmon fry survival. Earlier work in Lake Washington indicated cottids were the most important prey item (45% by volume), however salmonids were also important (14%, Stein 1970). Largemouth bass probably have little interaction with juvenile sockeye salmon or fry. During emigration to the lake, largemouth bass are probably inactive due to low water temperatures. In the summer and fall, juvenile sockeye salmon inhabit the pelagic zone, whereas largemouth bass generally inhabit the littoral zone in water less than 6 m deep (Sublette et al. 1990). Salmonids consumed by largemouth bass will probably be more shoreline-oriented fish such as coho salmon, chinook salmon, or rainbow trout.

No salmonid fry were found in the stomachs of yellow perch. During the peak emigration period of sockeye salmon fry, little food was found in yellow perch stomachs. This was most likely due to spring spawning activities of yellow perch. Earlier work in Lake Washington demonstrated that the lowest volume of food per stomach (April-December) occurred in April (Costa 1979). Similarly, Paxton and Stevenson (1978) found that in Ohio reservoirs the greatest occurrence of empty stomachs and minimum stomach content volumes were observed during the April spawning period. Yellow perch can feed under ice throughout the winter and thus are apparently active year round (Ney 1978). There has been little evidence of any predation on juvenile sockeye salmon by yellow perch in Lake Washington (Nelson 1975; Costa 1979).

## CONCLUSIONS

1) We did not observe a numerical response of predators at the mouth of the Cedar River during the sockeye salmon fry emigration. However, there was an apparent increase of predators after the peak of the fry emigration in May and June.

2) Results indicated that the highest predation rates occur in the lower 600-m reach of the Cedar River. Except during high flows, this reach is mostly slow-velocity water backed up from Lake Washington. In the lower Cedar River, cutthroat trout, rainbow trout, coho salmon, and prickly sculpin appeared to be major predators of salmonid fry.

3) In both the lower Cedar River and southern Lake Washington, cutthroat trout appeared to have the highest consumption rates of sockeye salmon fry and presmolts.

4) Although consumption rates of salmonid fry by prickly sculpin were generally low, they may be the most important predator because they appear to be the most abundant. Results indicate further work on predation by prickly sculpin is needed.

5) Low predation levels were observed in the littoral zone of southern lake Washington. Small numbers of sockeye salmon fry were observed in stomachs of cutthroat trout, juvenile coho salmon, rainbow trout, prickly sculpin, and smallmouth bass.

6) Data indicate that a dredging project to deepen the channel of the Cedar River would probably create additional foraging sites for piscivorous fishes in areas of reduced water velocity. An increase in predator abundance may increase the overall predation level and have a negative impact on the emigrating sockeye salmon fry population. However, because the number of most predators is relatively small, this impact may be minimal. Further evaluation of predator consumption rates and population levels is needed.

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